Assessing Sedimentation in Port Basin a Case Study of Pim Port Lhokseumawe-Aceh

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Abstract. A port is an important infrastructure for shipping activities where a process of loading/unloading goods is taken place. Therefore, a port basin must be maintained from sedimentation due to waves and tides. A breakwater that is commonly implanted along the basin sides may also serve as the sedimentation protection, such as in the PIM Port. The port is also vulnerable to extreme waves as it was affected by the 2004 Tsunami with a major wave's impact damaged on buildings surrounding the area. The impact of waves and tides may produce sedimentation in the basin. The purpose of this study is to assess the sedimentation which occurs due to normal waves and tides in the port basin and to predict how much sedimentation may occur in the next 5 and 10 year. The assessment is based on the software Delft3D simulation. It was found that sedimentation occurred in the PIM port basin with an average sedimented volume of 932,078 m3/year. The value can be considered as the initial stage of sedimentation for further study on modeling the impact due to the Tsunami wave.

Keywords: *Port basin, Sedimentation, Delft3D*

1. Introduction

Pantai Bangka where the PT. Pupuk Iskandar Muda (PIM) port is located is part of Lhokseumawe city which is situated along the coastal line of 4^{o} – 5^{o} N dan 96^{o} – 97^{o} E. The place was affected by the Tsunami extreme waves in the year 2004, which caused damage to surrounding buildings and facilities. The PIM port has been built to facilitate the sea transportation need of the industries in the region. Aside from the port, the place is functioning as a recreational area. Understanding the coastal characteristic such as waves, tides, and sedimentation, and how is the impact of the waves on the facilities along the coast is a basis for the region's development and future expansion of both the port and city. Sedimentation is continuously built up due to wave propagation and tides. It has the potential to halt the activity of loading/unloading goods within the port basin. Although a breakwater has been implemented around the port basin, it is still crucial to analyze how much sedimentation is produced not only due to its vulnerability to extreme waves but also to anticipate the dredging need.

2. Literature Review

2.1 Port

Triatmodjo (2010:3) has defined a port as a coastal area enclosed by wave's impact, providing facilities for sea terminal including facilities of docks, cranes, and forklifts for loading/unloading process, also warehouses for storing goods in a longer period whilst on transit for further shipping.

2.2 Numerical Modeling

Numerical modeling is used to define the process of the coastal system into numerical equations. The simulation is useful to gain an understanding of the process of waves, tides, and sedimentation, and how they impact changes in bathymetry and topography of the modeled area.

Delft3D has been widely used for simulating the process of the coastal, river estuary, and delta areas. The model is also applicable for simulating waves, sedimentation, ecology, and water quality. The combination of Delft3D-Flow dan Delft3-Wave is used here to model the changes on the coastal morphology due to sedimentation. The sedimentation transport equation used is based on the Van Rijn (Li et al, 2013), as elaborated in Equation (1) to (5) in the following:

$$q_s = 0{,}012\,\bar{u}\,\frac{(\bar{u}-\bar{u}_{cr})^{2.4} d_{50} D_*^{-0.6}}{((s-1)g d_{50})^{1.2}} \quad (1)$$

$$q_b = 0{,}005\,\bar{u}\,h\left(\frac{\bar{u}-\bar{u}_{cr}}{((s-1)g_{d50})^{0.5}}\right)^{2.4}\left(\frac{d_{50}}{h}\right)^{1.2} \quad (2)$$

Dengan,

$$D_* = \left[\frac{g}{v^2}\right]^{1/3} D_{50} \quad (3)$$

$$\bar{u}_{cr} = 0{,}19(D_{50})^{0{,}1} log\left(\frac{12h}{3D_{90}}\right) \quad for\ 0{,}0001\,m \le D_{50} < 0{,}0005\,m \quad (4)$$

$$\bar{u}_{cr} = 8{,}50(D_{50})^{0.6} log\left(\frac{12h}{3D_{90}}\right) \quad for\ 0{,}0005\,m \le D_{50} < 0{,}002\,m \quad (5)$$

where:

D_{50} = median bed material diameter ((m);
D_{90} = 1.5 D_{50}
D* = non-dimensional diameter
ū = flow velocity (m/det);
ūcr = critical velocity (m/det);
h = water depth (m/det);
v = velocity along - y axis (m/det)
qb = bed load
qs = suspended load

3. Methodology

The Delft3D is used to simulate the coastal process due to waves, tides, and sedimentation. The study consists of three part which are: data retrieval, model parameters preparation, and simulation followed by the analysis of the result.

3.1 Study Area

The study area, as shown in Figure 1, is the PIM port basin located along the Pantai Bangka region. The port is used to facilitate the sea transportation for cargo, urea fertilization, and liquid ammonia. An accumulated sedimentation has been identified within the basin port due to waves and tides.

Figure 1. Study Area

3.2 Model Domain

Bathymetry and topography data are acquired from the Port Management. The data is used to model domain simulation of 10 m x 10 m grid. This grid layer, shown is Figure 2, is the input into model for the hydrodynamic and morphology simulation. The satellite image of the coastal region retrieved from the google earth.

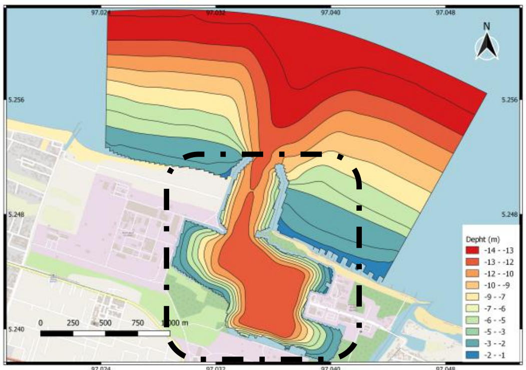


Figure 2. The model domain

3.3 Wind Data Analysis

Wind data consists of wind direction and wind speed is collected from PIM Port from 2009 to 2020. This data is used to build the windrose diagram, as shown in Figure 3, to define the dominant wind direction for calculating the design wave.

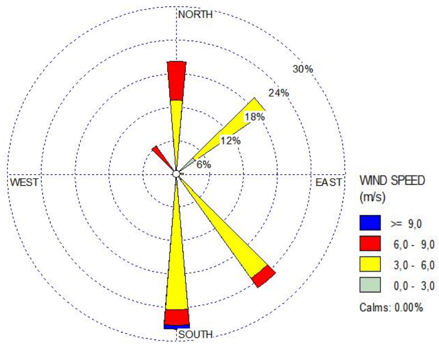


Figure 3. Windrose of year 2009 – 2020

3.4 Numerical Model for the Coastal Hydrodynamic and Morphology

Navier-Stokes equation is commonly used in the Delft3D, sediment transport, and other typical models (Giles, 2000). The equation is presenting the fluid movement differentially which describe the relation of changes rate within the variables. Sediment is constrained to a cohesive model. The boundary condition is defined as the fluctuation of the water surfaces (tides) and wind generated waves (Table 1 and Table 2). The sediment movement at the bed region is simulated by the Delft3D producing new bathymetry on every time step. The bed morphology characteristic has an influence on the interaction of the waves and the current at the bed region. This simulation is aim to obtain the morphologies changes within 5 and 10 year using the morfac factor for every waves direction based on the windrose.

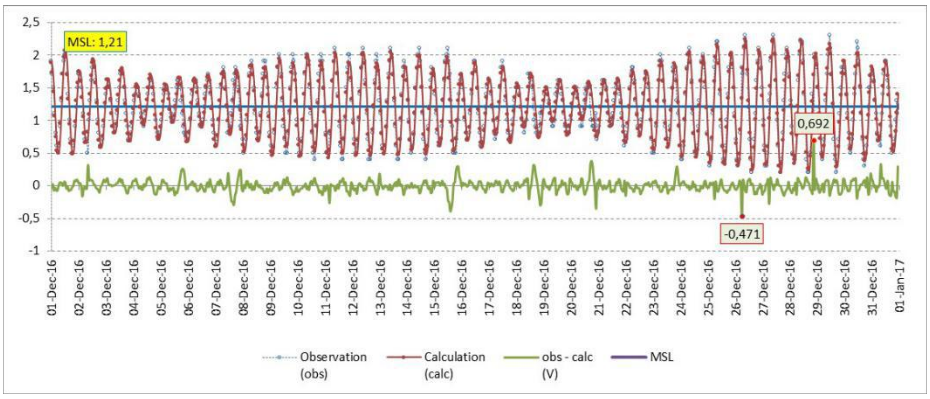


Figure 3. Tides chart

The input for the boundary condition for both the hydrodynamic and the morphology is the tides component (M2,K1,S2, dan O1) and waves data (Hs dan Ts), which simulating of the fluid movement from the wet grid in the domain. The harmonic component is the component of wave generator from the tides observation measurement data which grouped based on the amplitude high, the phases, and the frequency. The tides measurement is taken for 15 days to include the 4 main components, presented in Table 1. Based on graphic in Figure 3, it can be derived that two phase tides occurs in a day which can be categorized as semi diurnal type.

Table1. The tides harmonic component

Tides component	Amplitude (m)	Phase (deg)
M2	0.5921	323.5932
S2	0.2439	41.8993
K1	0.1455	180.9734
O1	0.0319	264.957

M_2 :Main component of the moon
K_1 :Component of the sun
S_2 : Main component of the sun
O_1 : Main component of the moon

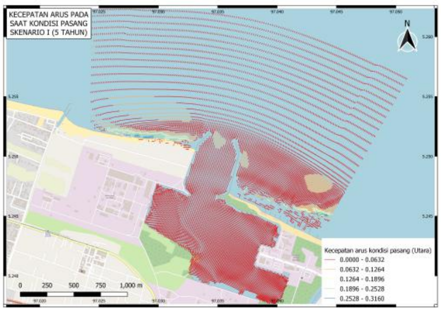
4. Result

4.1 Modeling the current and the waves

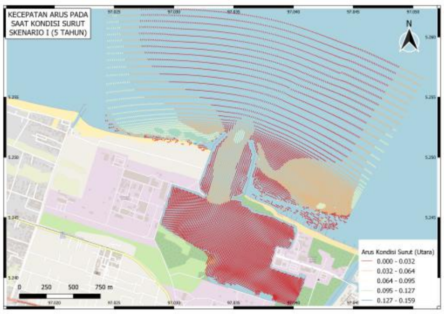
The current and the waves in the basin are influenced by the wind directions of the Northeast, the North and the Northwest.

a. Scenario 1 (5 year)

The result indicates the current velocity is 0,3 m/s for the highest tides propagation from North to South. The deviation occurs along the breakwater opening due to shoaling which triggered by the sudden change of water depth increasing the current velocity to 0,1 m/s. The pattern however is similar both for the lowest and highest tides.



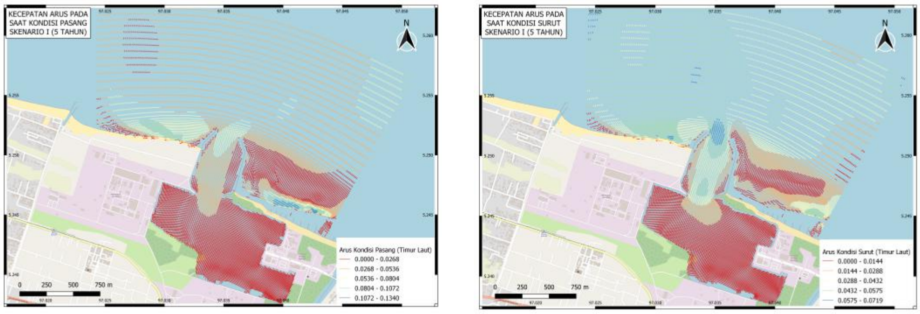
(a)



(b)

Figure 4. The current pattern in the PIM port Basin during the North wind (a) highest tides (b) Lowest tides

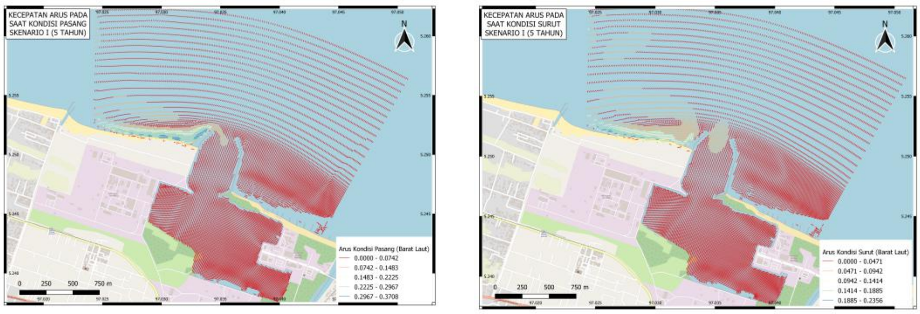
In reverse, the current propagation during highest tides from Northeast to Southwest is relatively small compared to that of North to South, which is 0,1 m/s. This occurs along the breakwater opening continuously decreasing on average 0,03 m/s and diffract on the right side of breakwater. During the lowest tides, the pattern is similar to that of the highest tides, where shoaling still occurs along the breakwater opening but the current velocity decrease to 0,07 m/s.



(a) (b)

Figure 5 The current pattern in the PIM port Basin during the Northeast wind (a) highest tides (b) Lowest tides

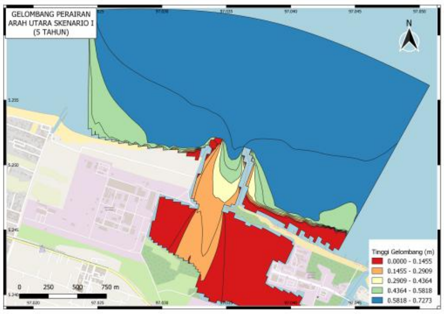
During the Northwest wind, the current velocity on highest tides is 0,38 m/s which relatively high. The current direction from northwest to southeast propagate toward the breakwater opening reducing the velocity to 0,1 m/s. Whilst, the condition during the lowest tides, the current propagate from inside the basin out, increasing the velocity on average 0,1 m/s – 0,2 m/s, due to contraction of the breakwater opening.



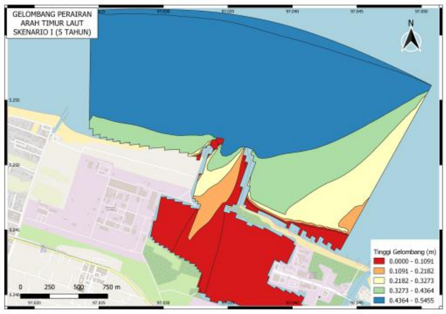
(a) (b)

Figure 6 The current pattern in the PIM port Basin during the Northwest wind (a) highest tides (b) Lowest tides

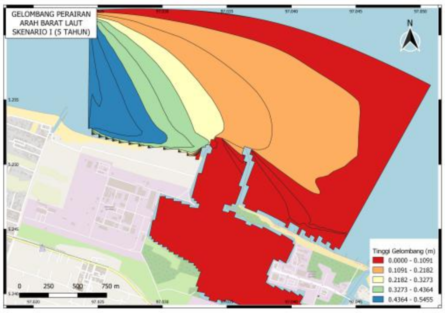
The simulation reveals that waves magnitude is 0.1 – 0.7 m. the waves propagation during North and Northeast wind relatively small. It is due to the reduction from the breakwater to 0,14 – 0,3 m. Similarly, during the west wind, the waves propagation toward the port basin also reduced to 0,1 m.



(a)



(b)

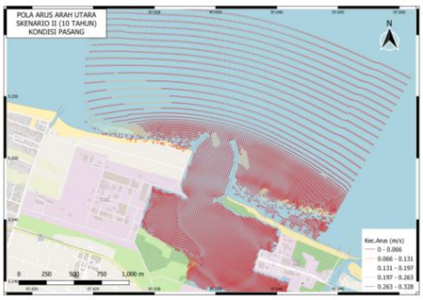


(c)

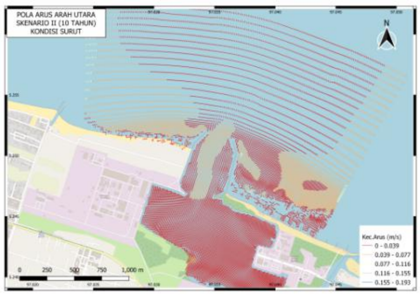
Figure 7. The waves pattern in the PIM port Basin during the North wind (a) northeast (b) northwest (c)

b. Scenario II (10 years)

On the scenario II, the simulation result is relatively similar to that of scenario I. The current of the highest tides propagates from North to South having the velocity 0, 33 m/s. The current propagating toward the port is decreasing in velocity from the shoaling. During the lowest tides, the pattern of the propagation is the same. The current propagating leaving the basin also influenced by the shoaling factor reducing the velocity to 0,1 m/s.



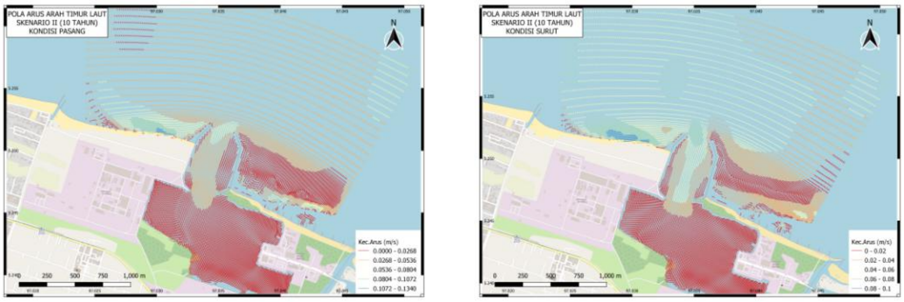
(a)



(b)

Figure 9 The current pattern in the PIM port Basin during the North wind (a) highest tides (b) Lowest tides

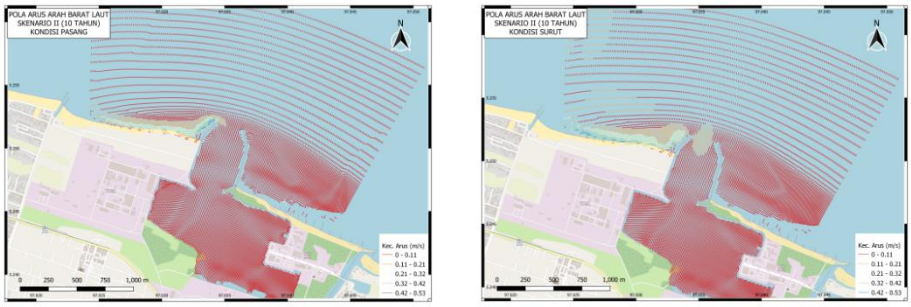
During the highest tides of the northeast wind, the current velocity is 0,08m/s propagating from the northeast to the southwest. Reaching the opening, the velocity reduced due to breakwater. During the lowest tides, the current velocity is 0,06 m/s.



(a) (b)

Figure 10 The current pattern in the PIM port Basin during the Northeast wind (a) highest tides (b) Lowest tides

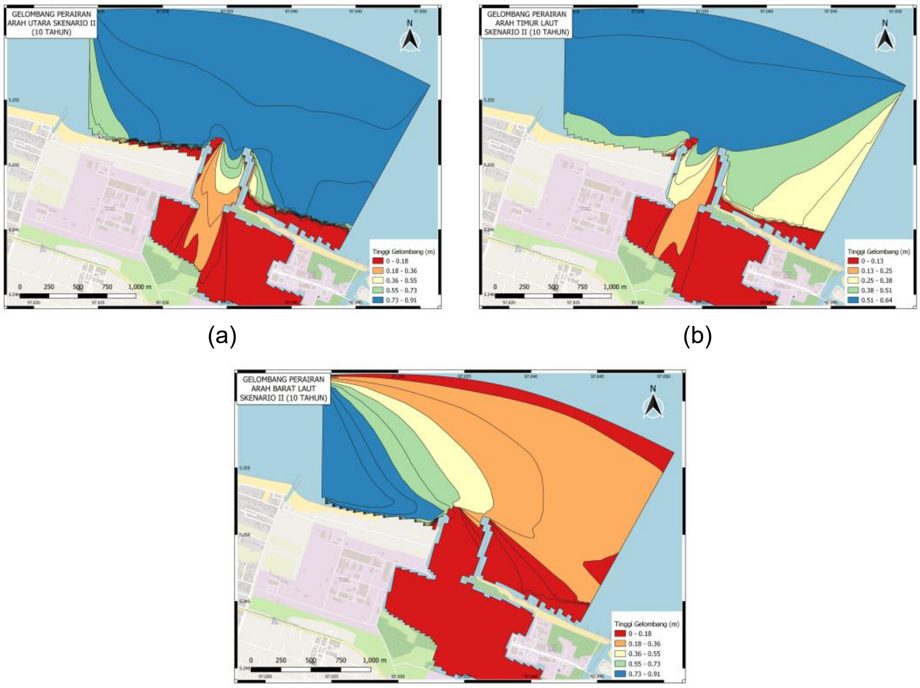
During the highest tides of northwest wind (scenario II), the current velocity is higher compared to that of the highest tides north and northeast wind which is 0,53 m/s. The current propagating from northwest to southeast toward the port basin is reducing the velocity to 0,1 m/s. During the lowest tides, the current velocity increase on average 0,1 – 0,2 m/s propagating outward the basin.



(a) (b)

Figure 11 The current pattern in the PIM port Basin during the Northwest wind (a) highest tides (b) Lowest tides

The wave simulation result from Delft3D-Wave reveals the wave height is on average 0,91 on the offshore. Along the propagation process toward the port basin, the waves is reduced by the breakwater. The shoaling affects the decreasing of the wave height from 0,25 – 0,35 m to 0,15 m reaching the port basin.



(a) (b)

(c)

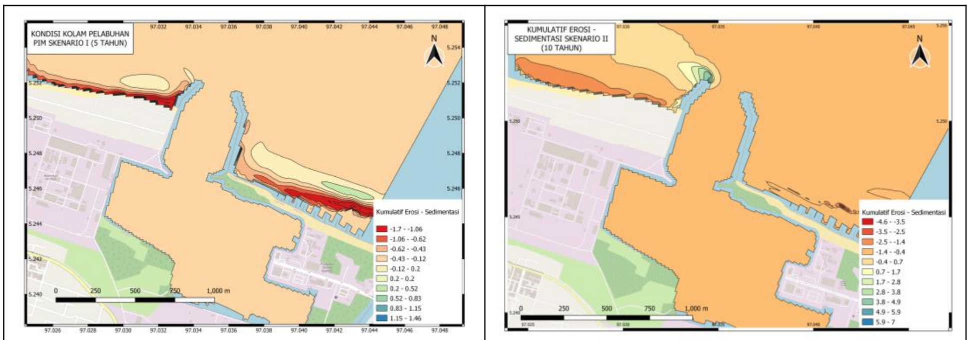
Figure 12. The waves pattern in the PIM port Basin during the North wind (a) northeast (b) northwest (c)

4.2 Erosion – Sedimentation Prediction

The change of coastal morphology is both of a natural process due to waves, wind, and increasing sea surface elevation, and of unnatural process such as human activities sand exploitation, coastal reclamation, and others. Abrasion and erosion on coastal line occur from continuous process of eroding land or accumulating sand along the line.
Supported by the measurement data and waves transformation which are wave height, water depth, and wave direction, the sediment transport can be estimated by modeling. The modeling is used to predict the longshore and onshore sediment transport which applied in analyzing the change of the coastal morphology.

PIM Port Basin

The waves and current triggered by the wind from north, northeast and northwest direction affect the erosion and sedimentation within the port basin. It is presented in Figure 13 the location of erosion and sedimentation in the basin. Based on the simulation the water depth in the basin is decreasing for longer periods of time. In scenario I and scenario II, the sediment accumulations are 0,12-0,43 and 0,4 – 1,4 m, respectively. The breakwater defends sediment entering the basin, resulting less sediment in the basin.



(a) (b)

Figure 13 Erosion – Sedimentation accumulation, scenario I (a), Scenario II (b)

5. Conclusion and Recommendation

a. The modeling result reveals that the sedimentation in the basin increasing along the time, which suggest a regular dredging for maintaining the basin function.

b. The deposition process within the basin relatively not impacting the activities of loading/ unloading goods within the 10 year projection due to the breakwater placement along the basin boundary.

Based on the model result, the regular maintenance is required for supporting the activities of ships leaving, entering the port, and loading/ unloading goods at the docks.

References

1. Al'ala, M., Syamsidik, Rasyif, T. M., and Fahmi, M. (2015). Numerical Simulation of Ujong Seudeun Land Separation Caused by 2004 Indian Ocean Tsunami, Aceh-Indonesia. J. of Tsunami Society 34 No.3 159-172.
2. Arizal, (2011), Pemodelan Numerik Perubahan Morfologi Dasar Pantai Singkil dengan Menggunakan Delft3D, TGA, Fakultas Teknik Universitas Syiah Kuala, Darussalam-Banda Aceh.
3. Ananda, C. R., Syamsidik., dan Fauzi, A, (2020). Analisis Sedimentasi Kolam Pelabuhan Ulee Lheue Dengan Menggunakan Piranti Lunak Delft3D, Journal of The Civil Engineering Student, Vol. 2, No. 3.
4. Fachrurrazi dan Syamsidik, (2015). Aplikasi Simulasi Numerik untuk Estimasi Perubahan Morfologi akibat Tata Letak Pemecah Gelombang, Seminar Nasional SPI ke-2, Jurnal Teknik Sipil Unaya.
5. Fahmi. M dan Hafli, T. M. (2019). Simulasi Numerik Perubahan Morfologi Pantai Akibat Konstruksi Jetty Pada Muara Lambada Lhok Aceh Besar Menggunakan Software Delft3D, Jurnal Teknik Sipil Universitas Syiah Kuala, Vol, 8 No. 2.
6. L. Giles, J. V. Kester and D. Roelvink. On-line Sediment Transport within Delft3D-Flow. (WL, Delft Hydraulics, 2000)

7. Levy, B. S., and J. A. Patz. (2015). Climate change, human rights, and social justice. Annals of global health, 81 (3):310-322. doi:10,1016/j.aogh.2015.08.008.
8. Li, L., Qiu, Q., and Huang, Z. (2012). Numerical modeling of the morphological change in Lhok Nga, west Banda Aceh, during the 2004 Indian Ocean tsunami: understanding tsunami deposits using a forward modeling method. Nat Hazards 64, 1549-1574.
9. McMichael, A. J. (2014). Earth as humans' habitat: global climate change and the health of populations, International journal of health policy and management, 2(1): 9. doi:10,15171/ijhpm.2014.03.
10. Muhajjir. (2016). Study on Sediment Transport around Lampulo Fishing Port on Banda Aceh Coast [Thesis]. Department of Civil Engineering. Osaka University. Osaka.
11. Nengsih, S. H., Fachrurrazi, Syamsidik, dan Kato, S. (2017). Numerical Simulation for Estimating of Sediment Transport Due Layouts of Port. Proceedings of IGNITE- AICCE.